The Vexcel UltraCam Large-Format Digital Aerial Camera System

and

NAIP

Salt Lake City, 16 November 2004

Joe Thurgood

Topics

1. The Vexcel UltraCam
   - Photogrammetric Design
   - Image Quality
2. Operating with the UltraCam
3. Image Products
   - Pan-sharpening
   - Film vs. digital
4. UltraCam-based NAIP Products
   - Initial results

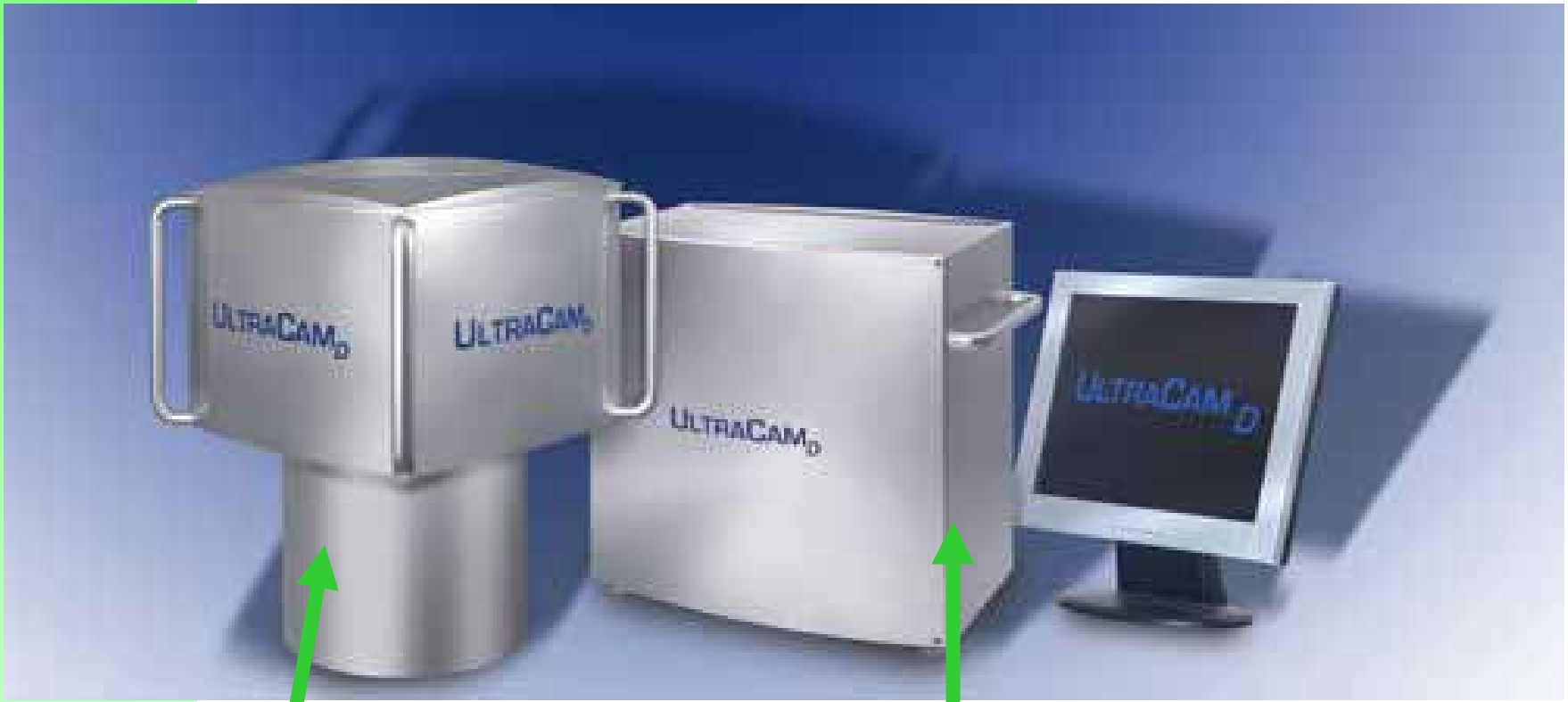
The Vexcel UltraCam Large-Format Digital Aerial Camera

Overview

What is the UltraCam ?

- 86 MegaPixel Frame Camera
- Black-and-White, Color and False Color Infrared Images
- Frame imagery compatible with standard photogrammetry software
- 1 frame per second

UltraCam System Components



Sensor Unit **Storage & Computing Unit**

System Components - Detail

Optical Assembly

Storage/Computing Unit

CCD Sub-assembly

Individual CPU/Storage

Camera Geometry

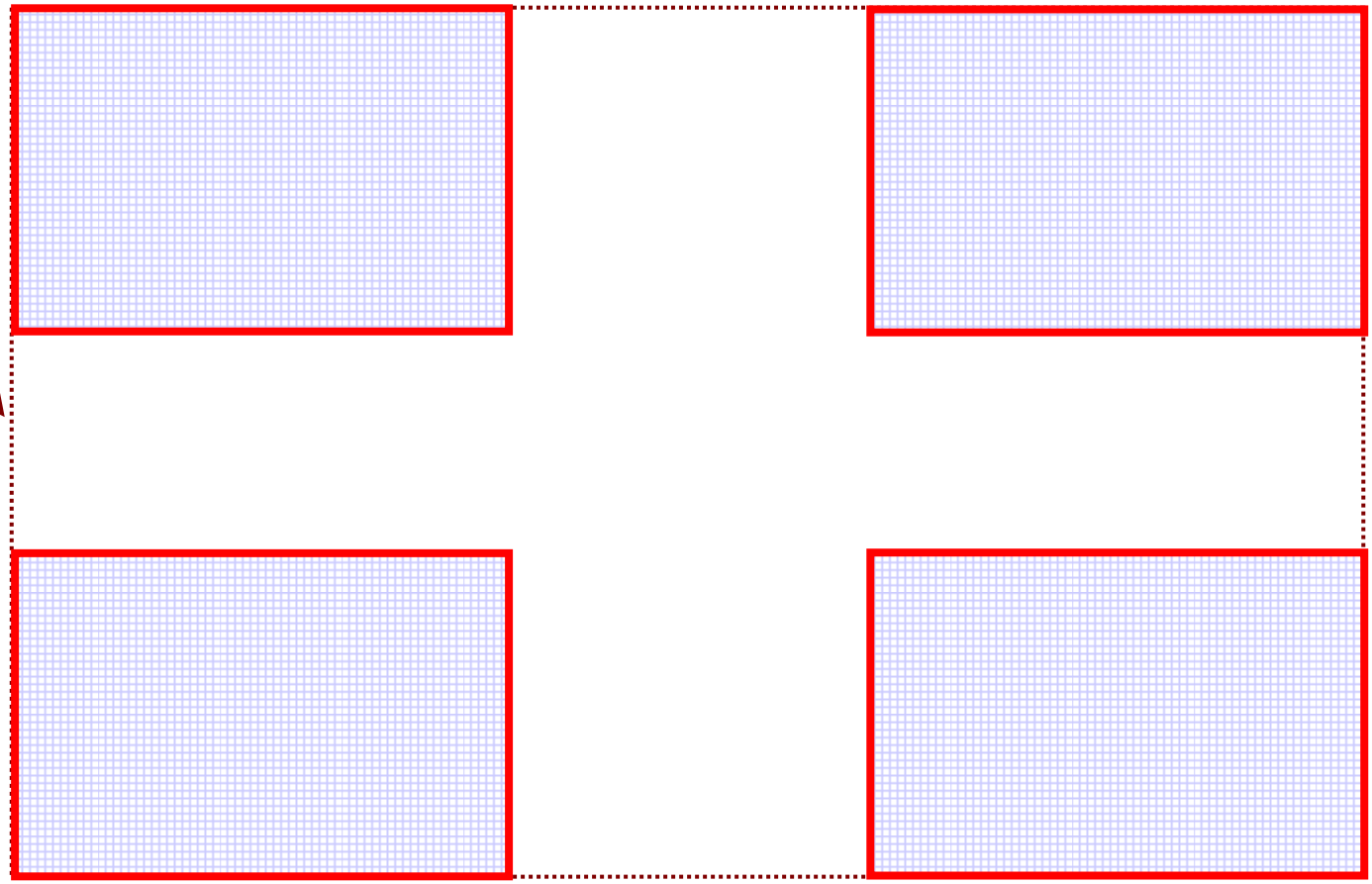
Master Cone
4 Color Cones
Panchromatic
ULTRACAM D

Traditional Film Geometry

Fiducials

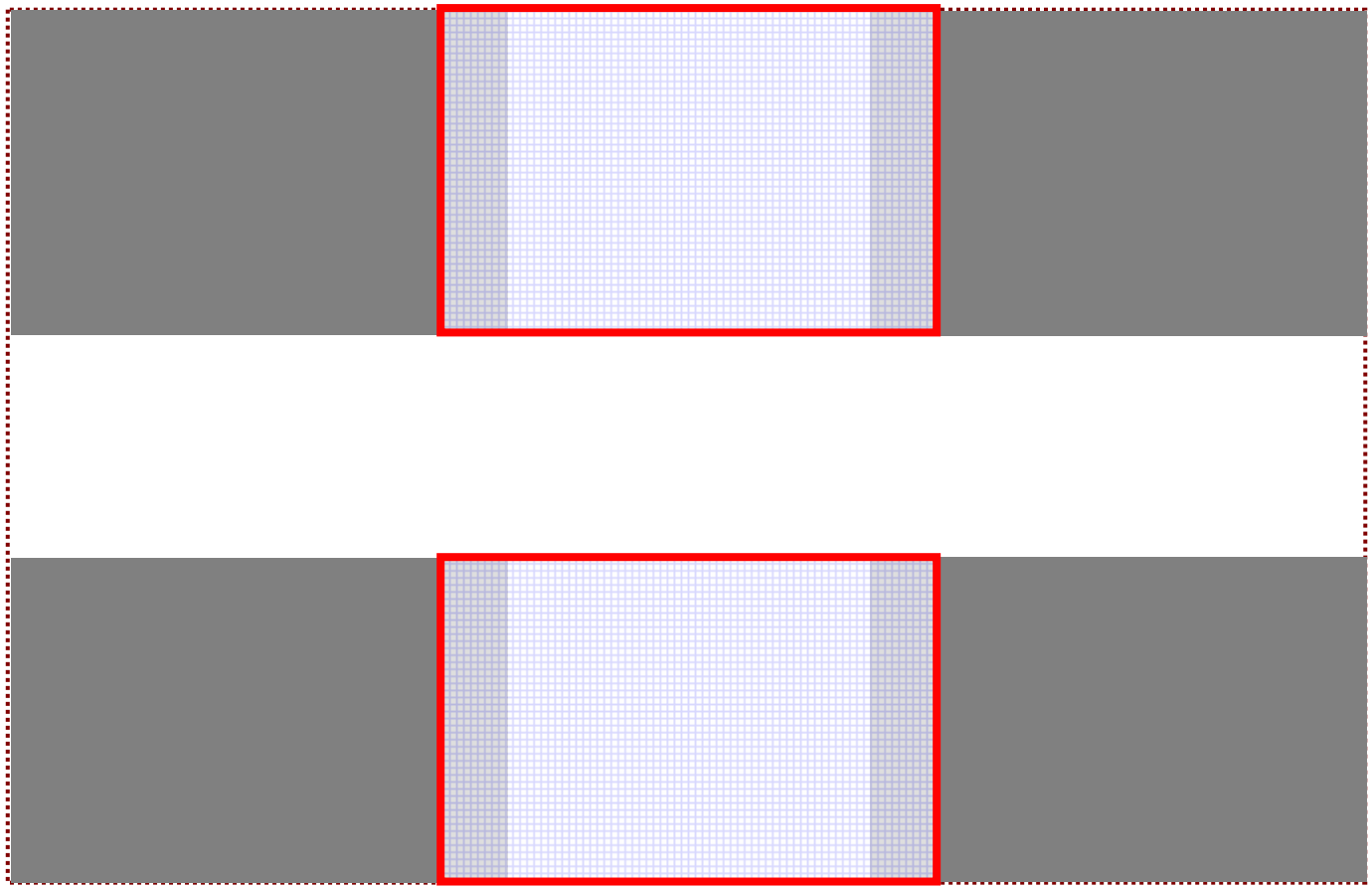
Master Cone Geometry

Full Scene



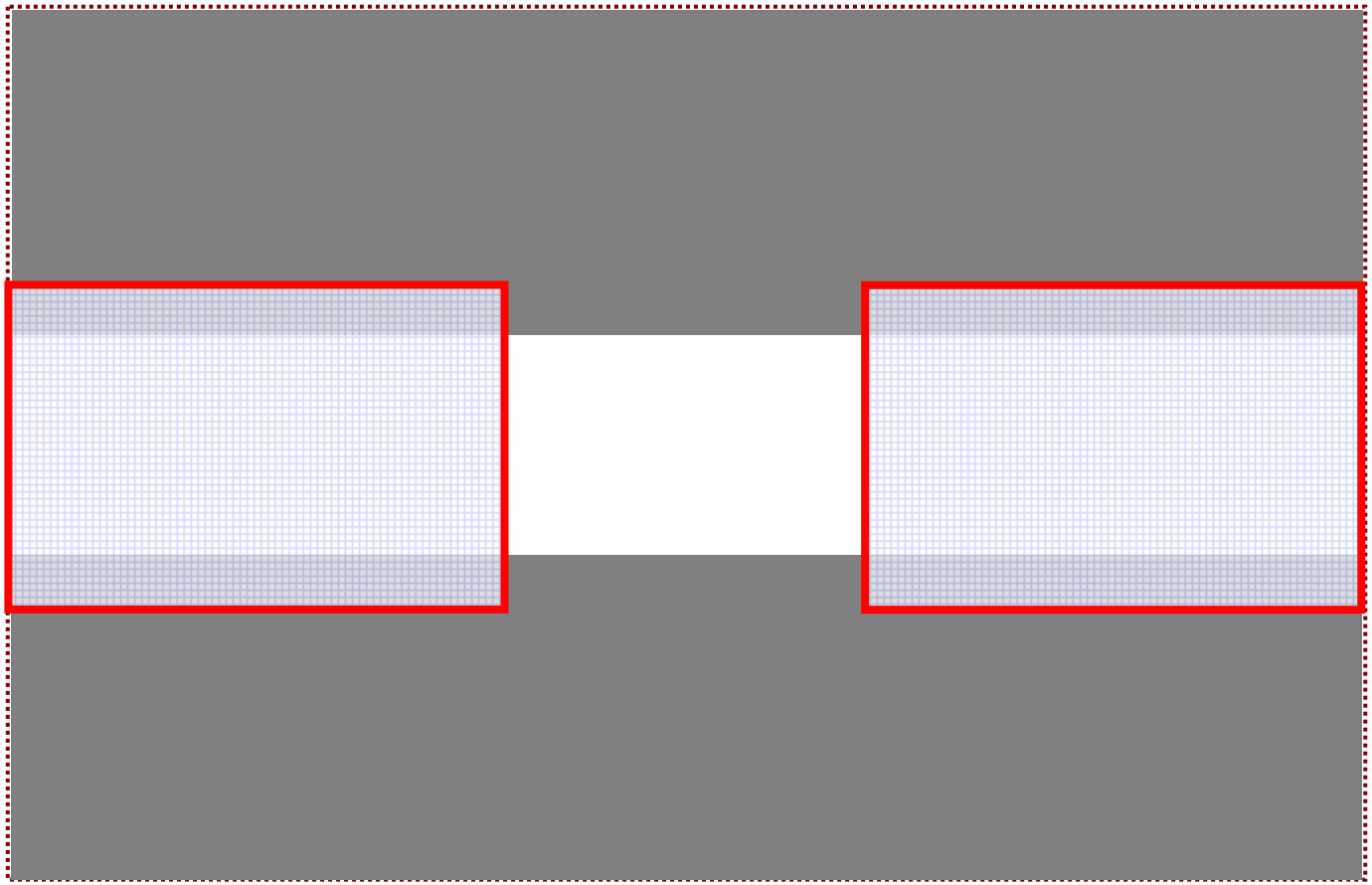
Master Cone with 4 Area Array CCDs

Additional Camera Cone - 1



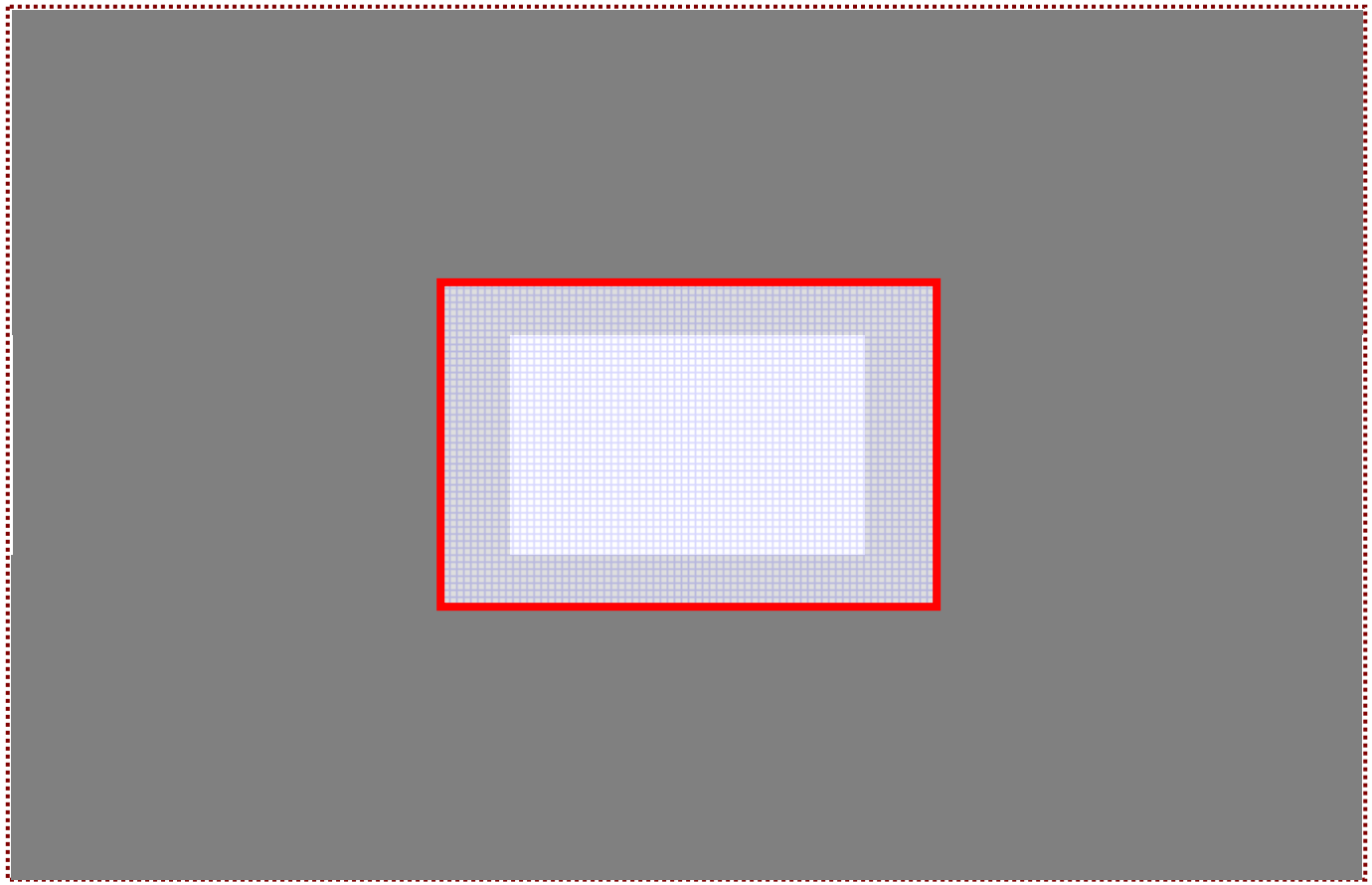
1st Slave Cone with 2 Area Array CCDs

Additional Camera Cone - 2

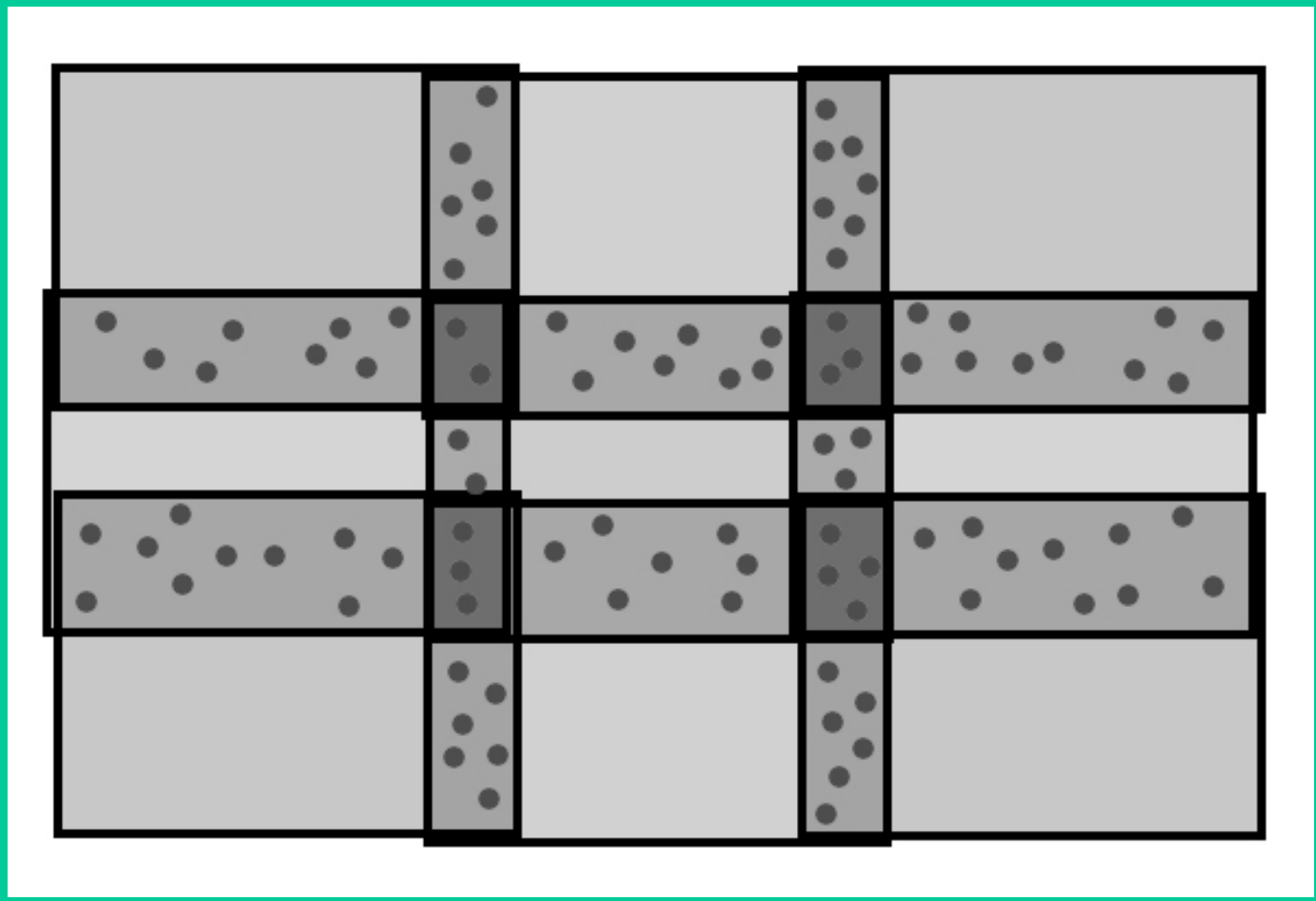


2nd Slave Cone with 2 Area Array CCDs

Additional Camera Cone - 3



3rd Slave Cone with 1 Area Array CCD



Tie Points at overlapping areas

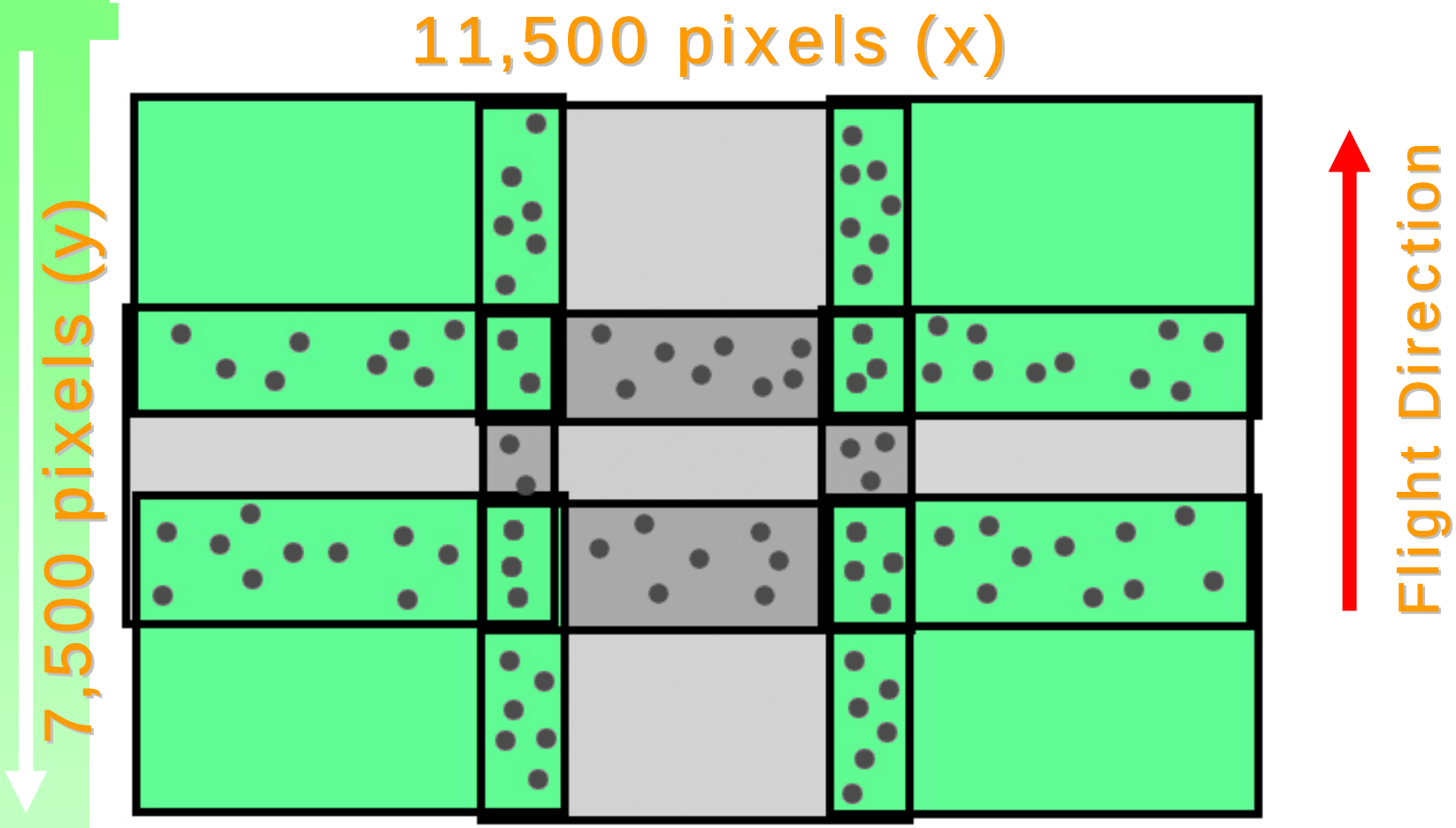
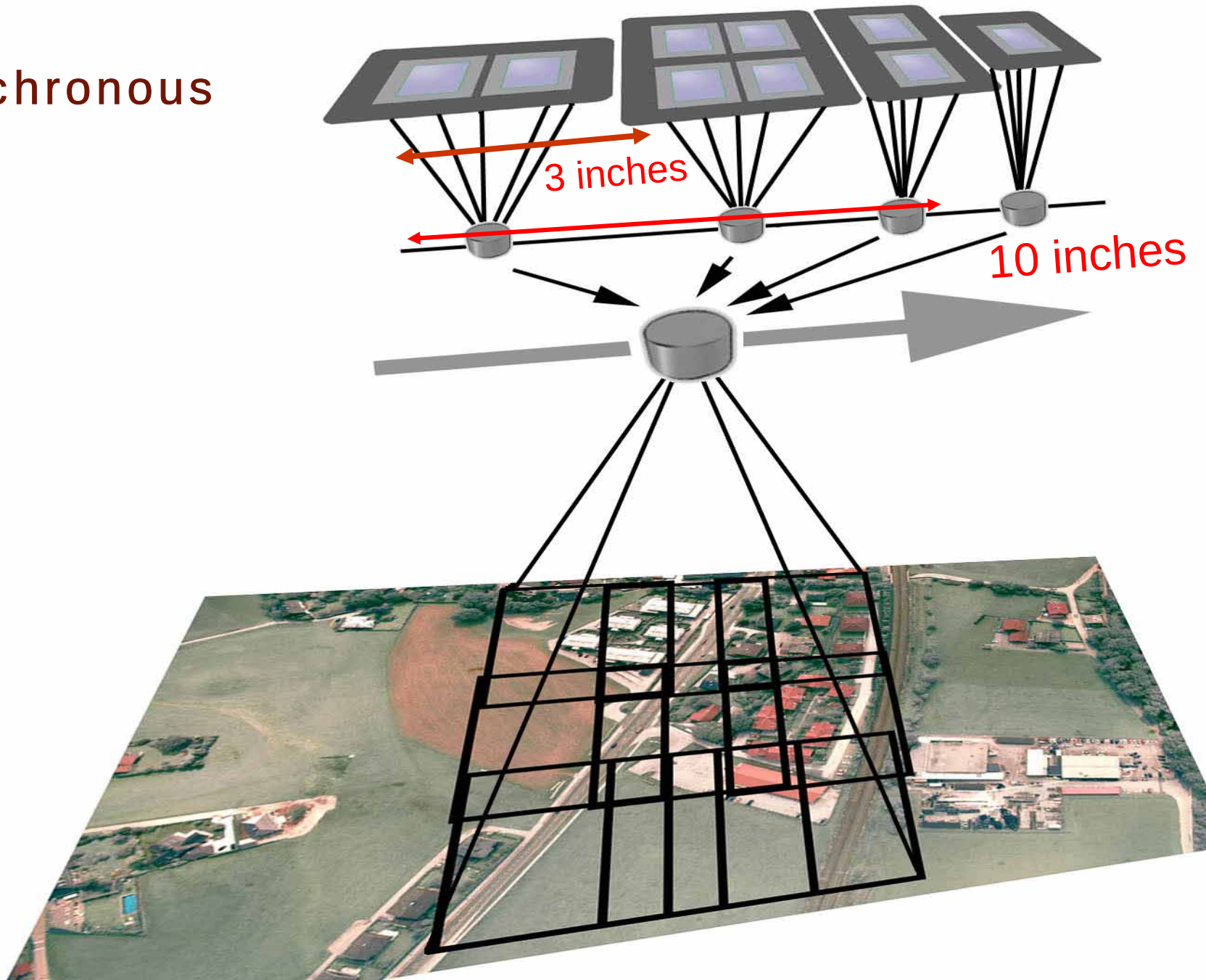


Image Geometry is based on the Master Cone with its 4 CCDs

Synchronous

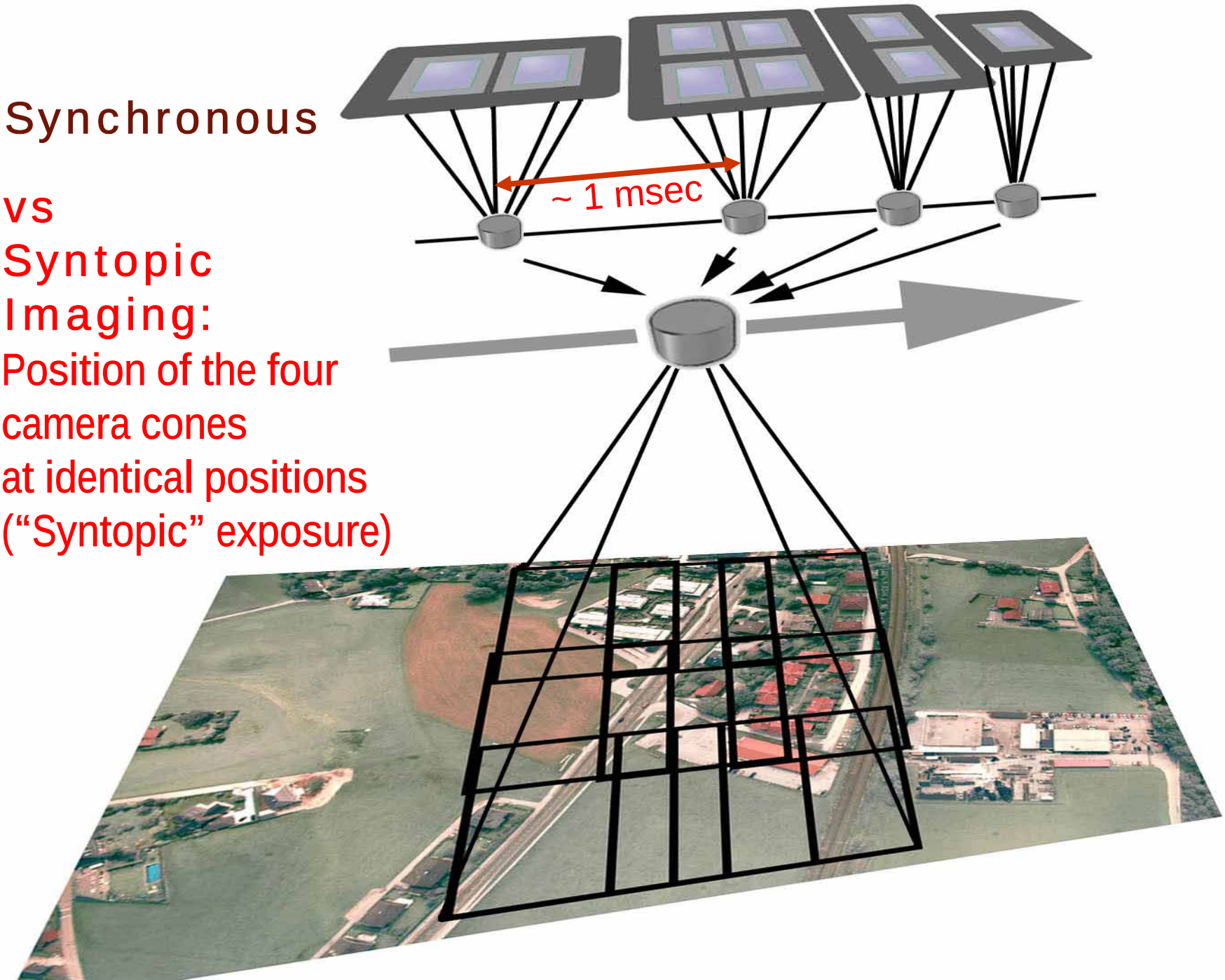


Synchronous

vs

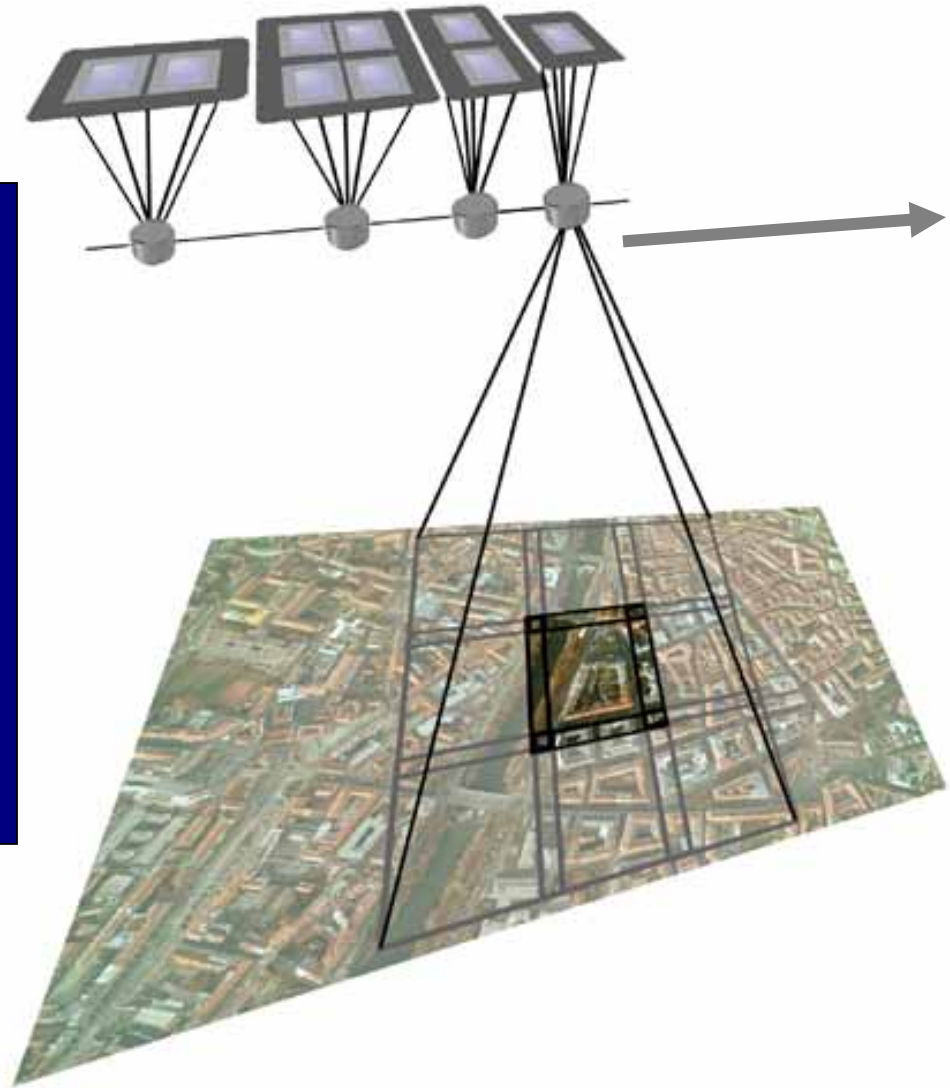
Syntopic Imaging:

Position of the four camera cones at identical positions (“Syntopic” exposure)

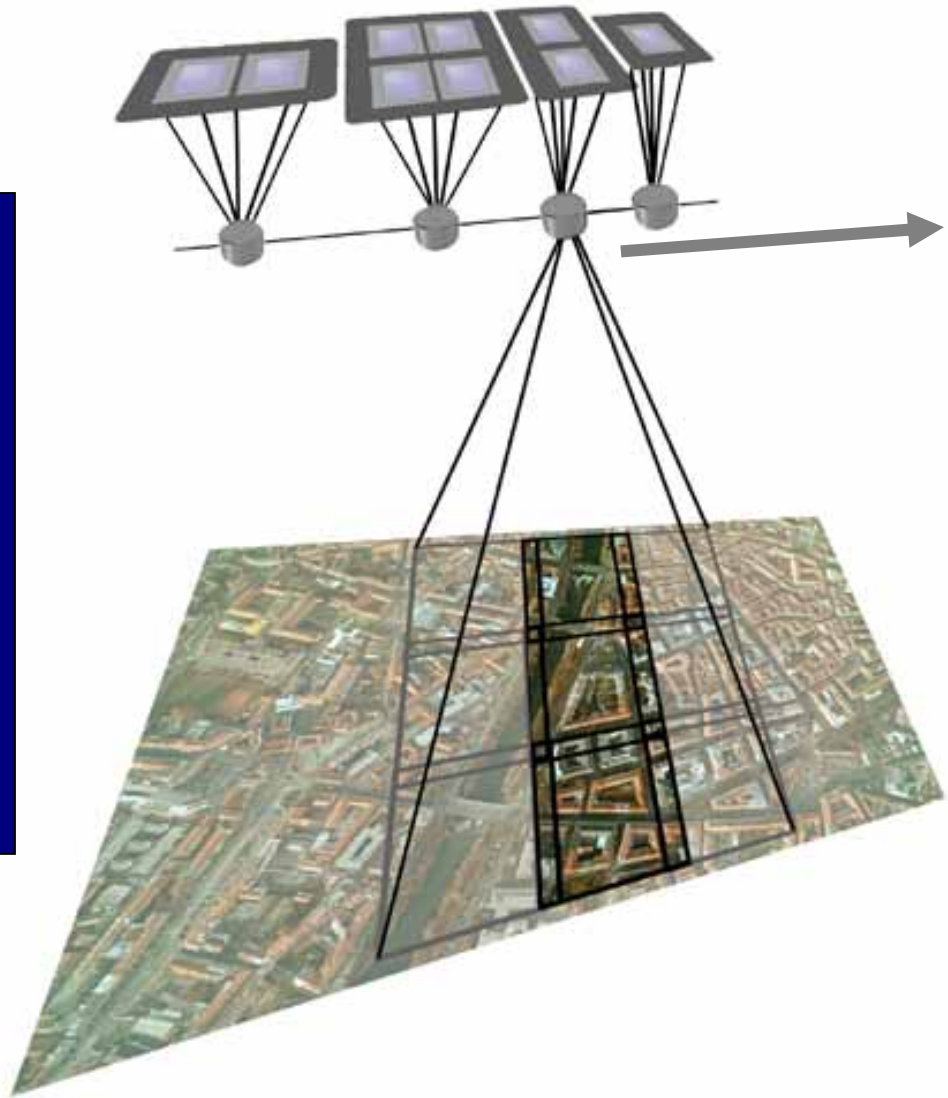


VEXCEL

For each full image,



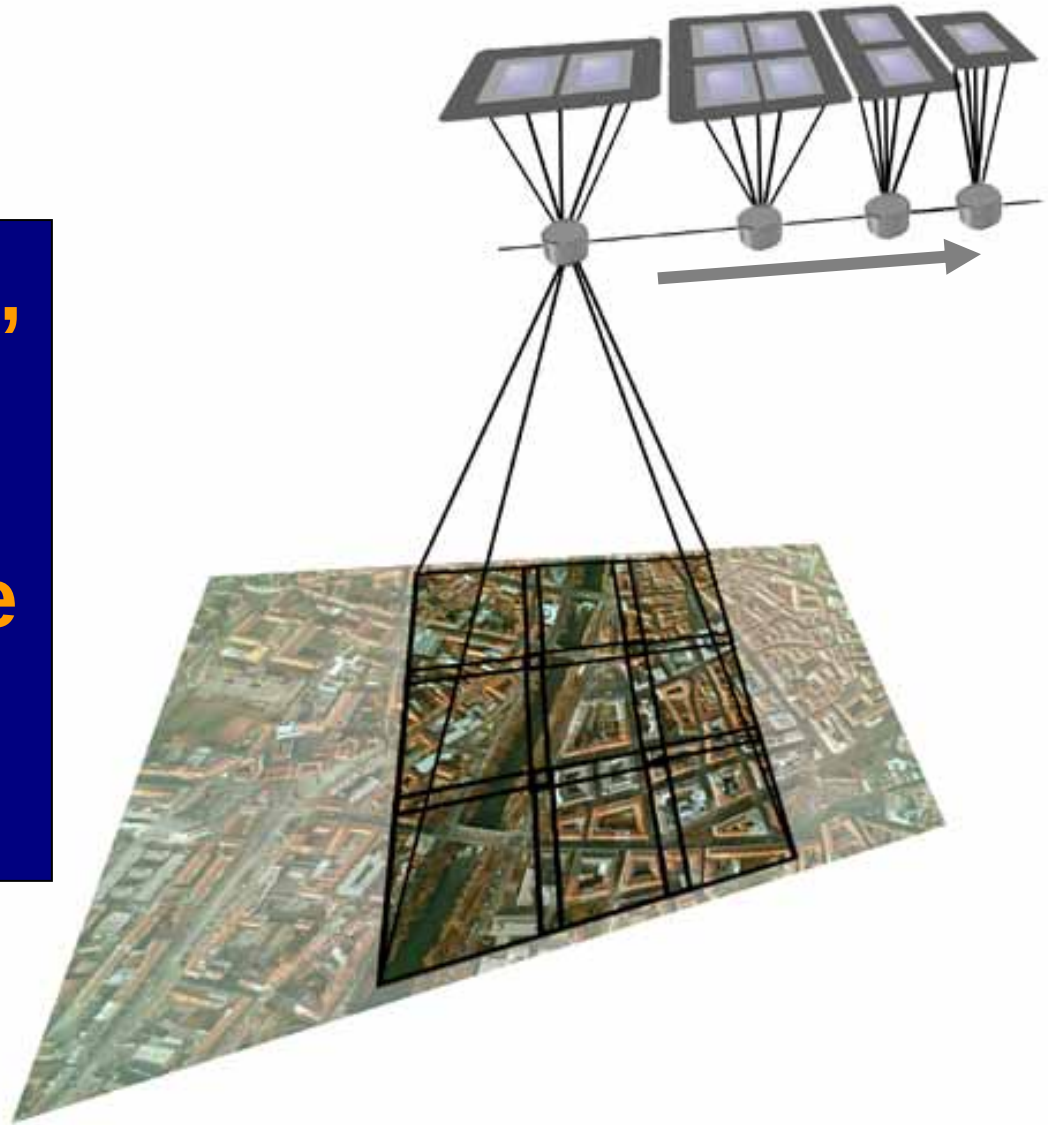
For each full image, the UltraCam exposes all



For each full image, the UltraCam exposes all subframes

VEXCEL

For each full image, the UltraCam exposes all subframes from the same effective camera station



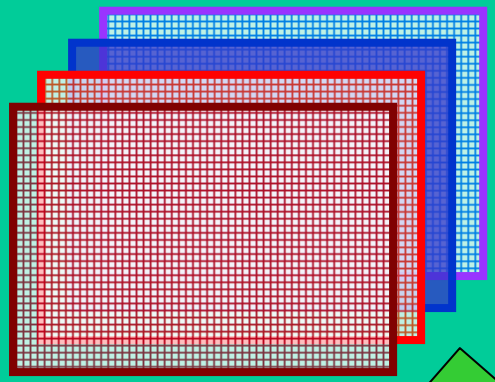
For each full image, the UltraCam exposes all subframes from the same effective camera station

Producing a single central perspective with no differential parallax

Multispectral Imaging

RGB and NIR

Cone # 5,6,7,8, each 1 Sensor Element



RGB/IR bands merged with pan scene

Full Scene

4 Slave Cones with 1 Area Array CCD capture multispectral data

Single Image:

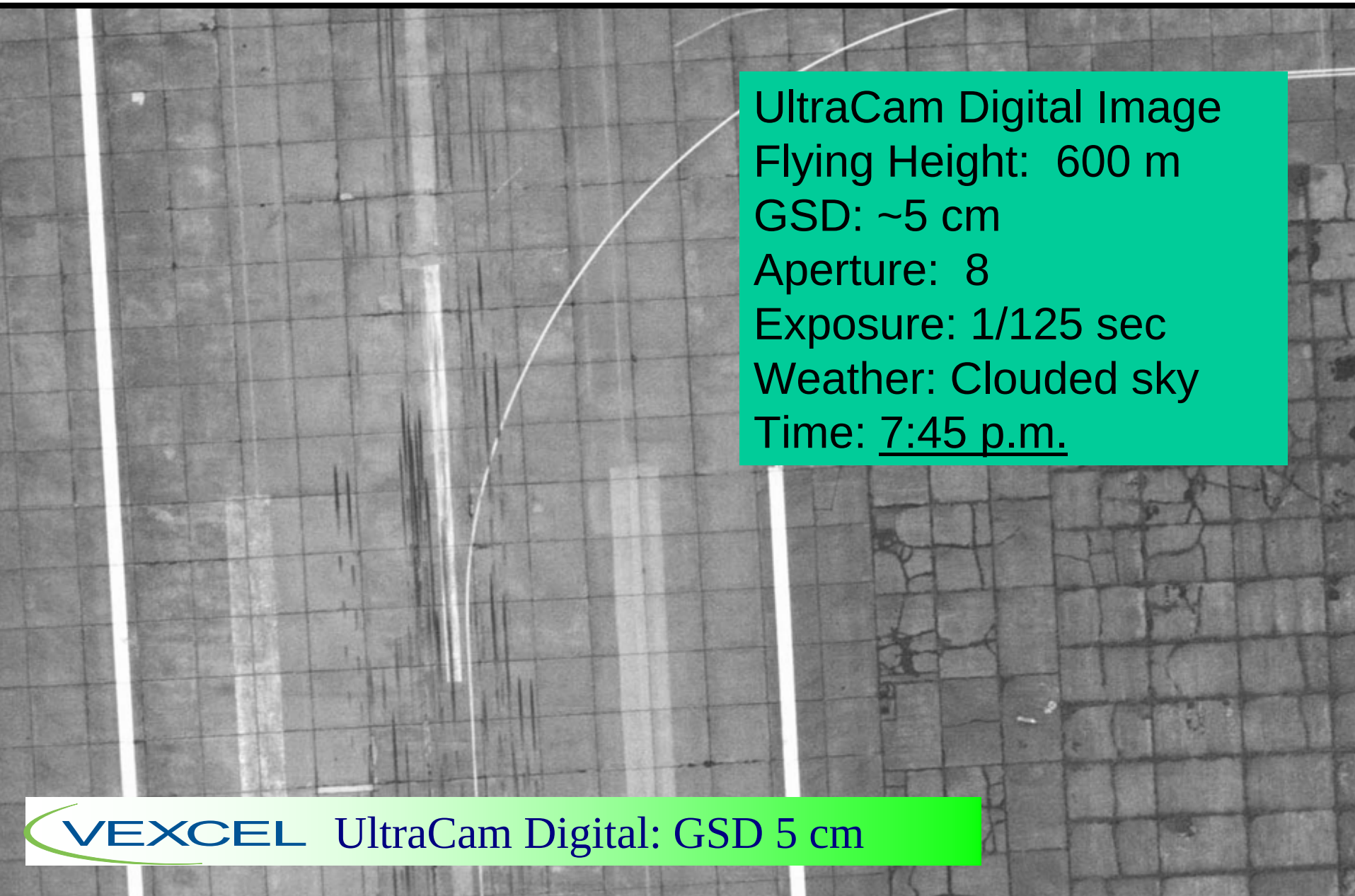
- Seamless 11,500 by 7,500 pixels
- Calibrated and interior oriented
- < ± 2 µm geometric accuracy
- 86 MPixels x 5 (= pan + 4 bands)
- > 1 frame / second

Standard Full UltraCam Image

Radiometric Quality

- 14-bit analog/digital conversion
  - Low system noise (~1-1.5 bits)
  - Produces full 12-bit image content per band
- Increased dynamic range permits
  - Longer useful flying windows
  - More useful manipulation of the image data

Low Light Conditions

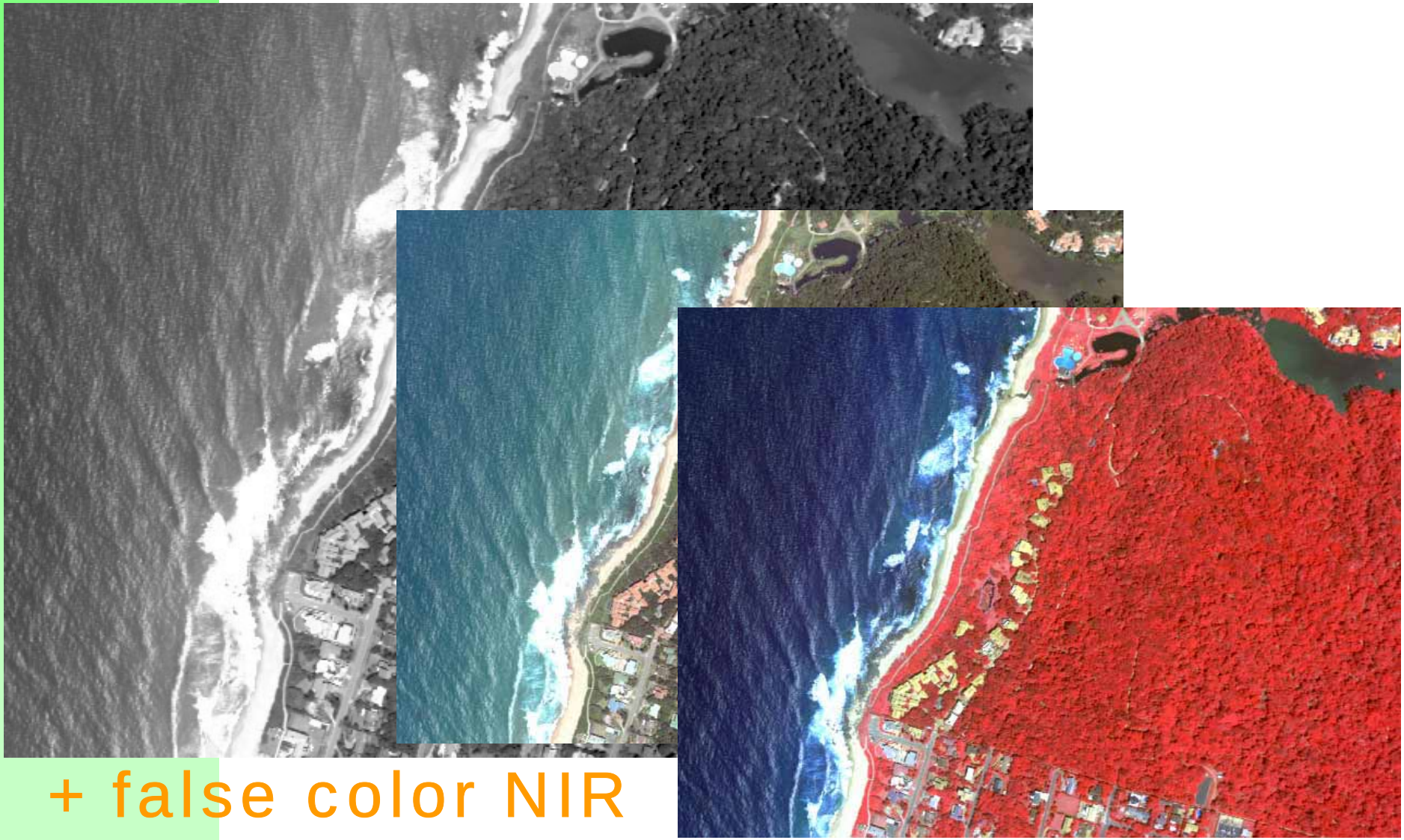


UltraCam Digital Image
Flying Height: 600 m
GSD: ~5 cm
Aperture: 8
Exposure: 1/125 sec
Weather: Clouded sky
Time: 7:45 p.m.

VEXCEL UltraCam Digital: GSD 5 cm

High Resolution Pan

+ true color RGB



+ false color NIR

Full scene assembled from 9
panchromatic subframes pan-
sharpened with color channel

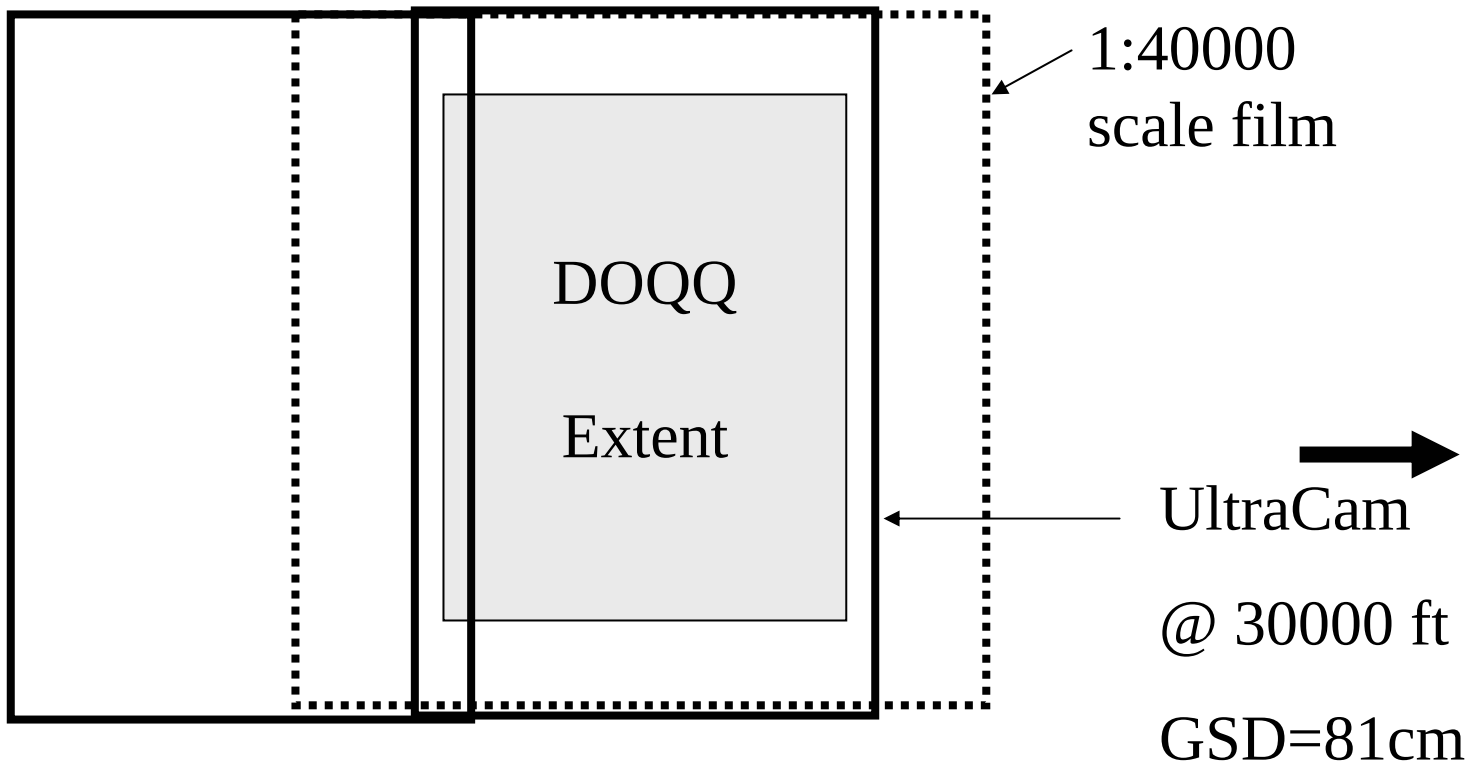
Universal Imaging Capabilities

UltraCam Digital: GSD 8 cm

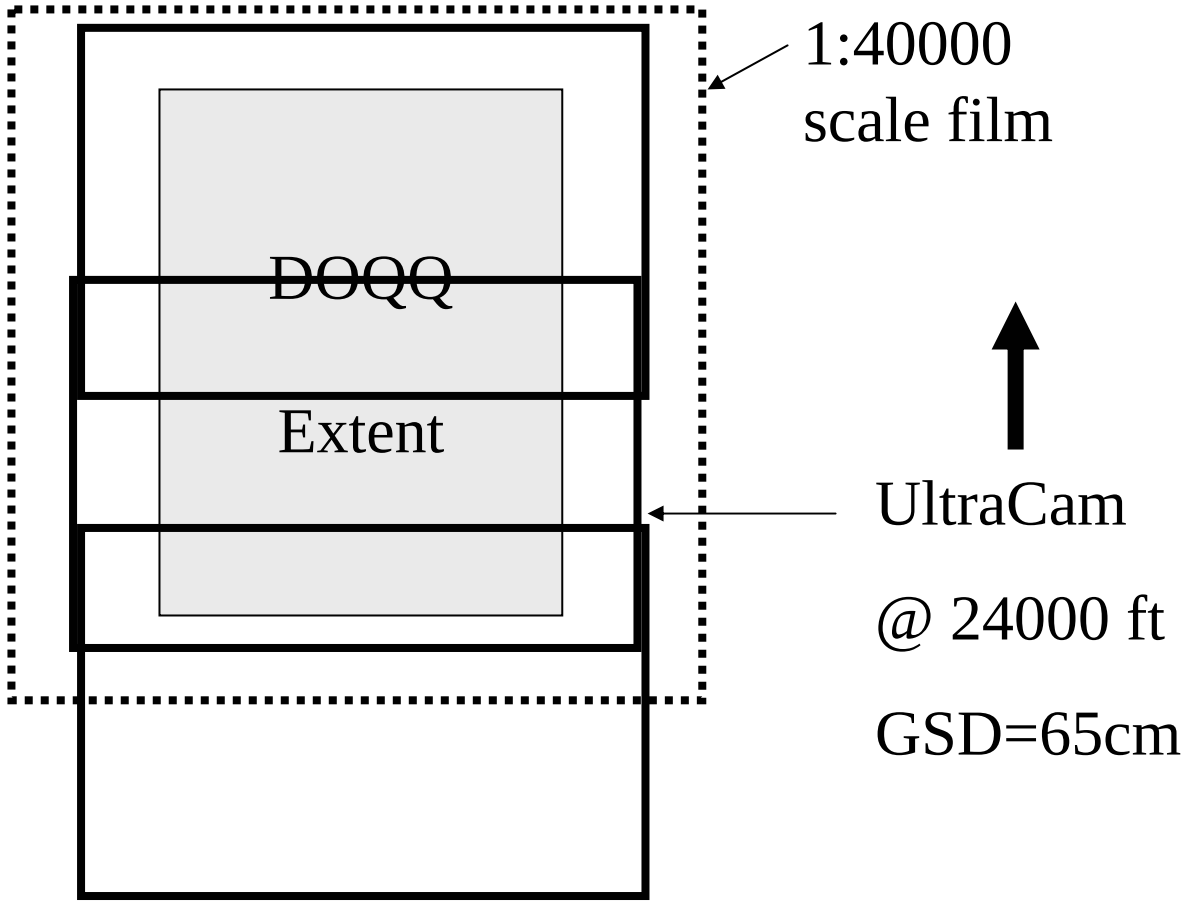
Imagery courtesy of PASCO Corporation, Japan

UltraCam Operations

Imaging Geometry – 1



Imaging Geometry - 2



ULTRACAM D
ULTRACAM D

Recording

Record

2127

Graz

Possible Captures: 1286

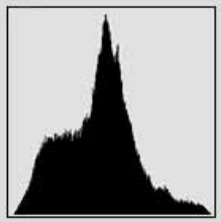
ETS: A SPT: None
CM: CTI: 0.75 s
FMC: ✓ STC: ✓
TvP: ✗

Av F 8

Tv s * 1/45

AGL ft 1640

GS kt 67



Tv: 1/32 Capture: 8 [570]

14:09
28 Jän 04

Pan-sharpening

Pan-sharpening

- Ratio of ~1:3.5 between pan and multispectral data in UltraCam
- Permits meaningful information content in all bands
  - Otherwise must compromise dynamic range within spectral bands, or ability to collect all 5 bands simultaneously
- Color vs. Texture
  - The visual system has many more panchromatic cones than color rods
  - Visually we focus on texture and edge detail
  - Automated image analysis / computervision also focuses on texture and edge detail

Digital vs. Film

Comparison of digital pan-sharpened color and color film

Film vs. Digital

- Visual quality
- Ability to match
- Accuracy of matching
- Effective resolution

Visual Quality

Input data set 1

- Analog stereo pair:

Input data set 1

- Digital stereo pair:

Input data set 2

Test flights: Morrison by Sanborn

Digital: $UltraCam_D$

00250 & 00251rgb.tif

Film:

anlglo0306 & anlglo0406.tif @ 14 µm

Input data set 2

- Analog stereo pair:

Imagery courtesy of Sanborn Map Company

Input data set 2

- Digital stereo pair:

Visual Comparison

- Data set 2:

analog

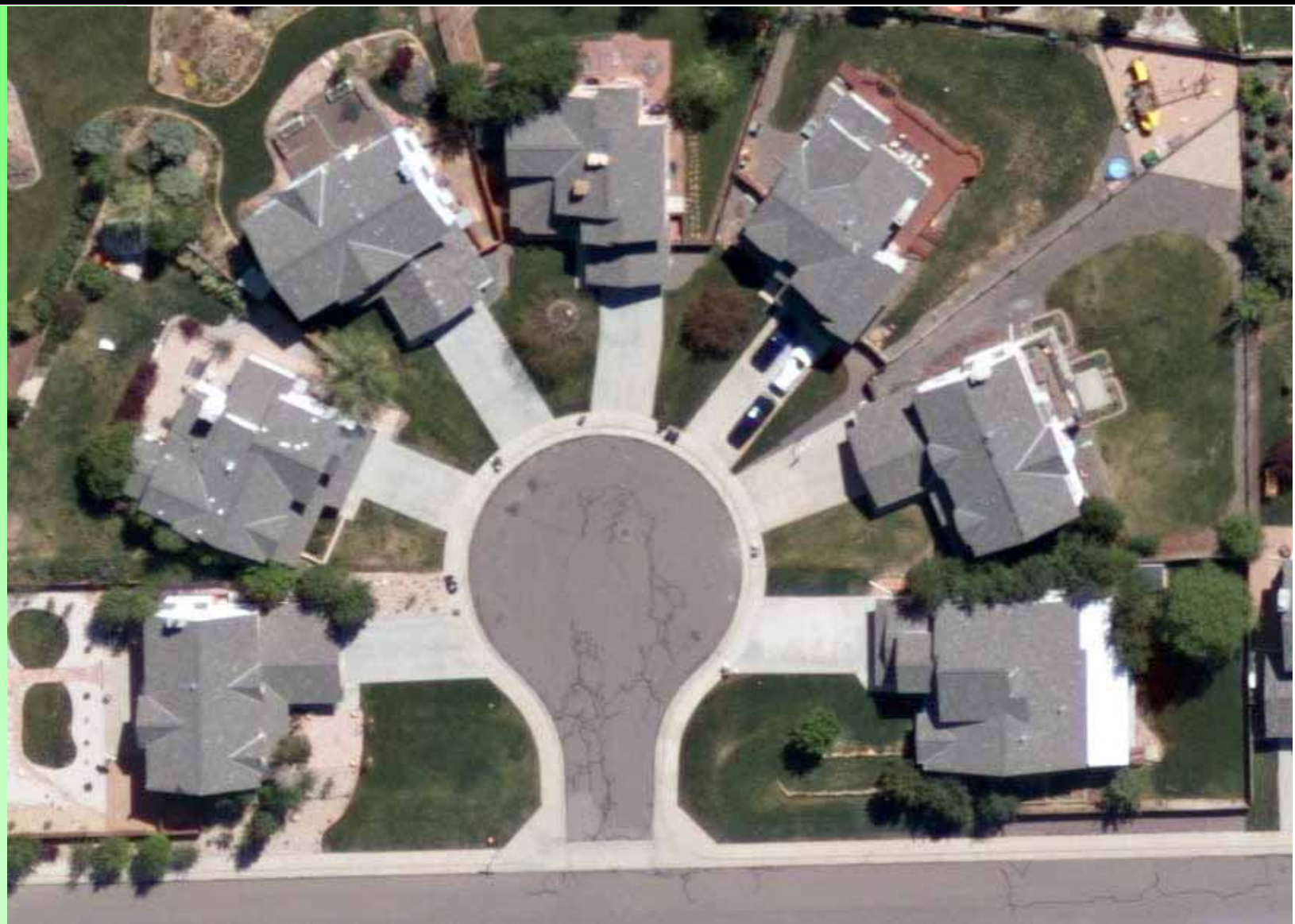
digital

Imagery courtesy of Sanborn Map Company

Analog / scanned film

Imagery courtesy of Sanborn Map Company

Digital



Visual Comparison

- Data set 2:

analog

digital

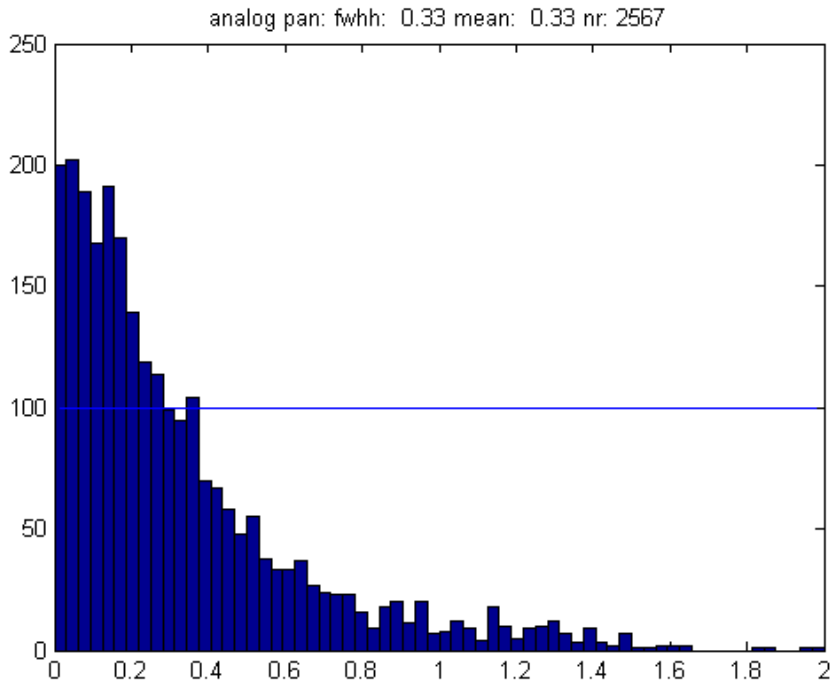
Imagery courtesy of Sanborn Map Company

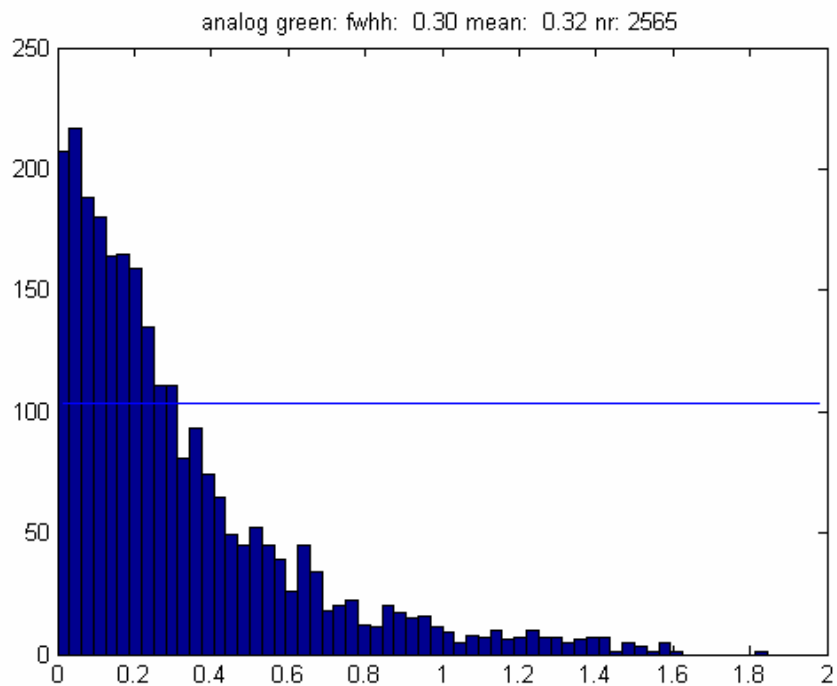
Ability to Stereo-Match (for AT and DEM Extraction)

Comparison of film and pan-sharpened digital color

Stereo matching - FILM

- Test 1, data set 1: FILM



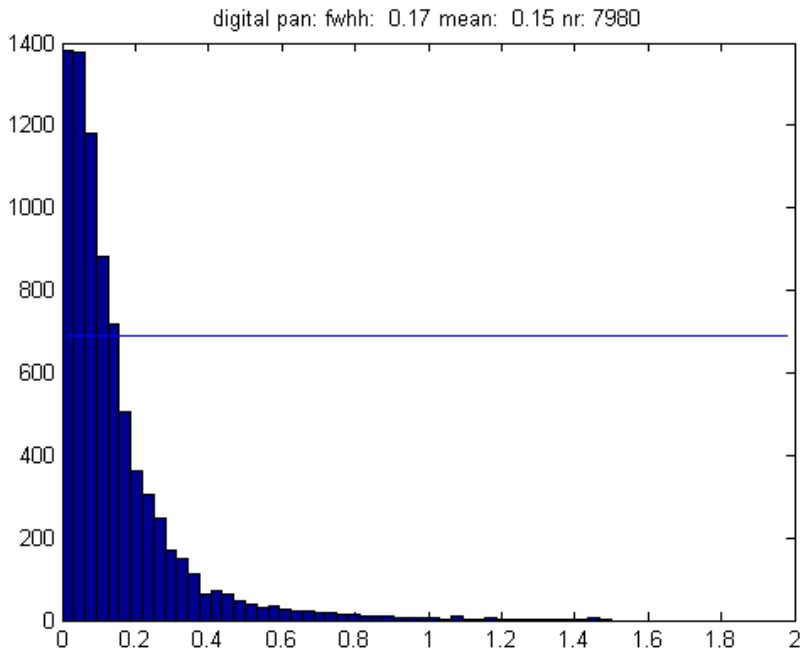


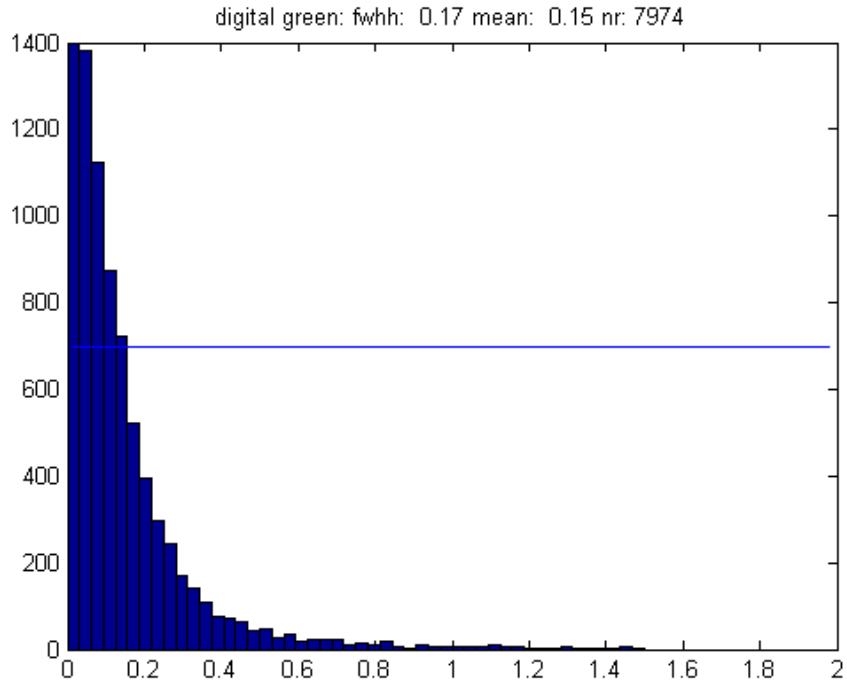
pan: ± 0.33 pixel

green: ± 0.30 pixel

Stereo matching - DIGITAL

- Test 1, data set 1: Digital





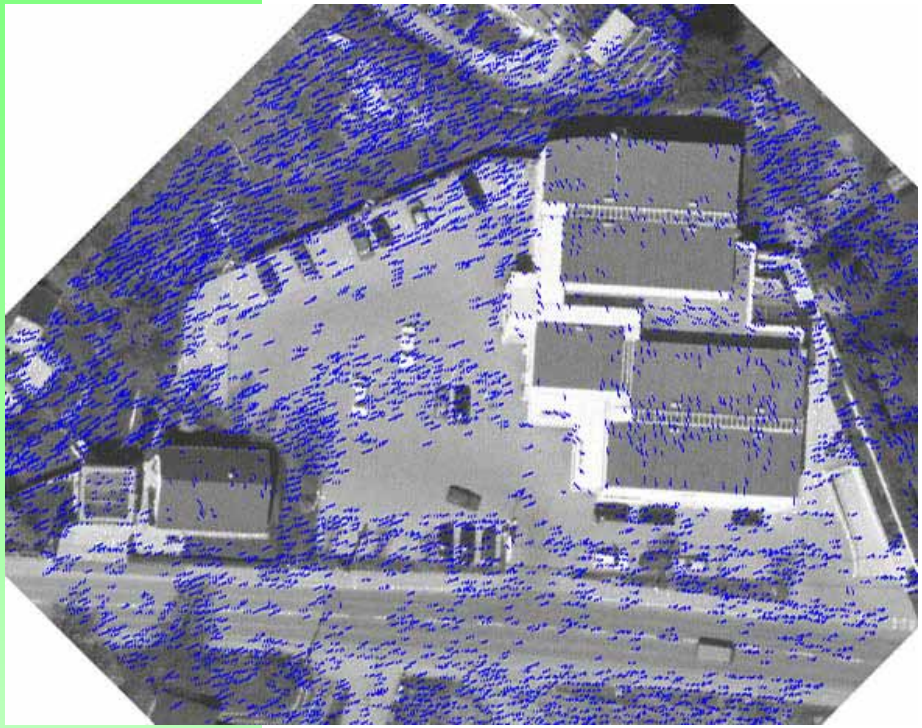
Panchromatic: ± 0.17 pixel

Pansharpened green: ± 0.17 pixel

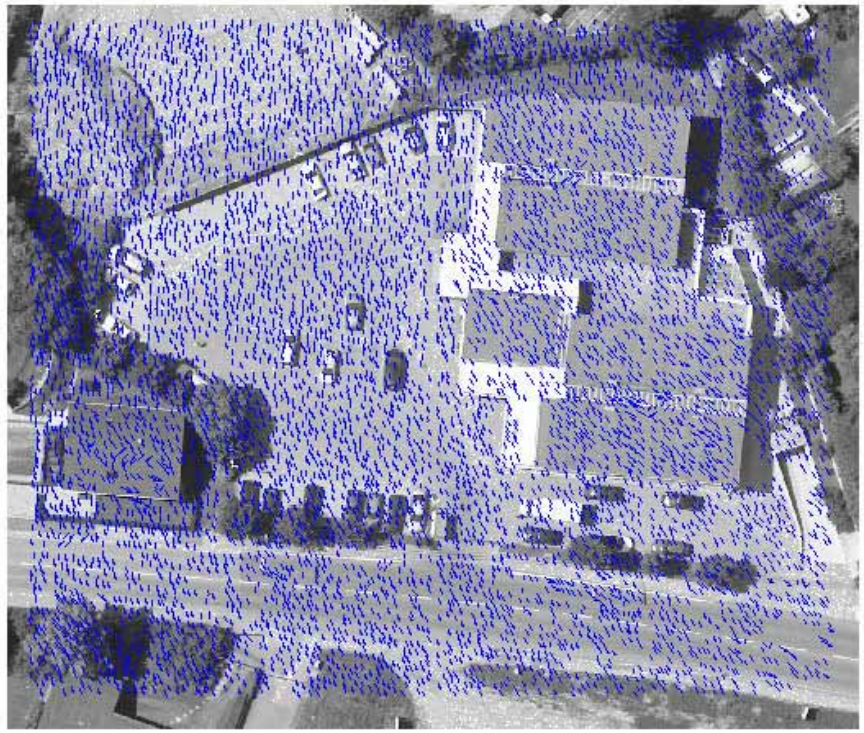
Stereo matching

- Tiepoints successfully matched:
  - 80% digital
  - 26% scanned film
- Digital matching is tighter
  - Subpixel accuracy almost twice as high
- Reflection of higher information content, lower noise

Stereo matching in smooth areas



analog



digital

In the film image the matching in homogeneous regions (road, parking lot, roof) fails and no match points can be collected.

Effective Resolution

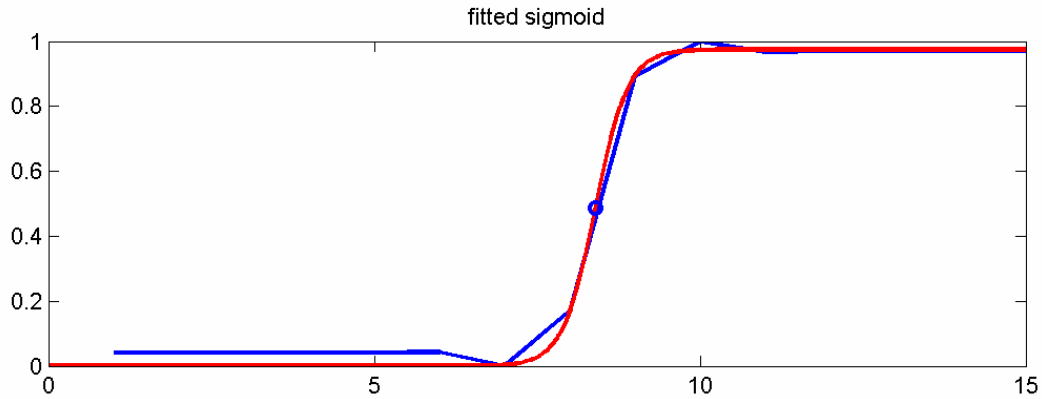
Comparing film and (pan-sharpened) digital color

Edge Response

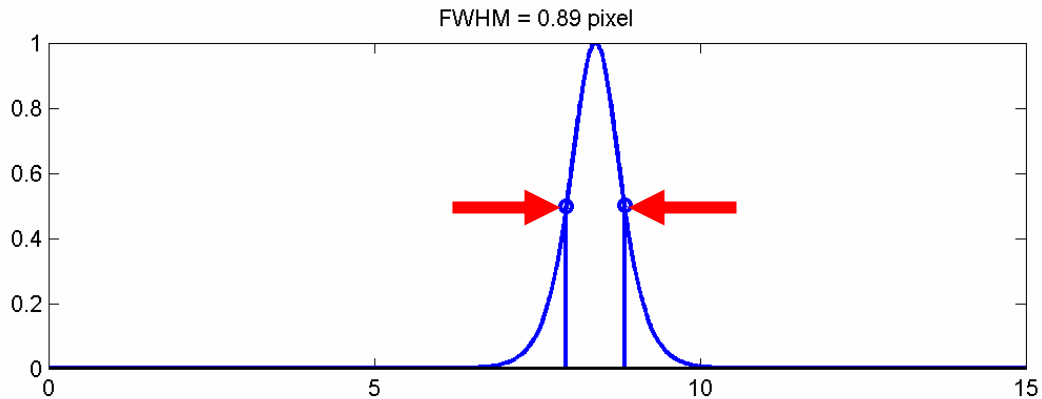
- By examining edge detail in images, we can determine a standard measure of resolution: ability to discriminate fine detail
- Method:
  - Fit curve to measured edge profiles
  - First derivative (slope) gives us an edge response
  - Full Width of edge response at Half Height (FWHH) is measure of resolution

Edge Response

- Synthetic edge



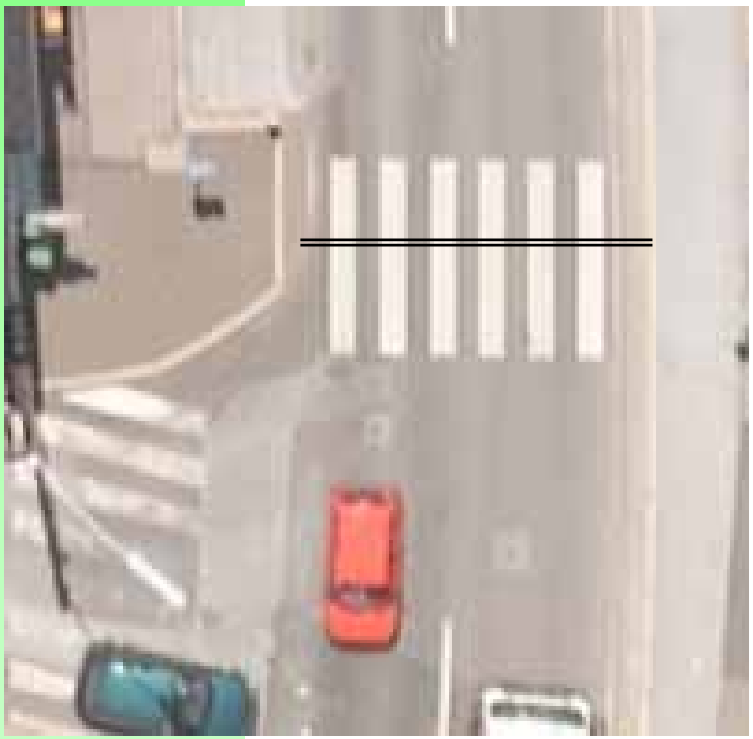
Blue: measured profile
Red: fitted edge function



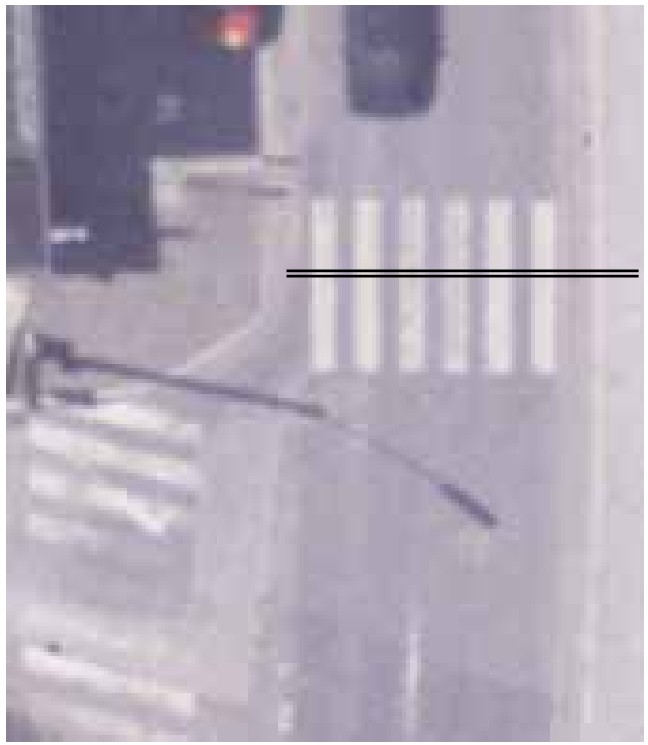
Blue: derived point spread function
Red: standard measure of resolution

Measured Edge Profiles

- Test 1: Pedestrian crossing



Digital: UltraCam



Analog Film, @ 20µm

Measured Edge Profiles

- Test 2: Shadows of houses on the road

analog

digital

Measured Edge Profiles

- Test 3: Morrison, edges from road to sidewalk

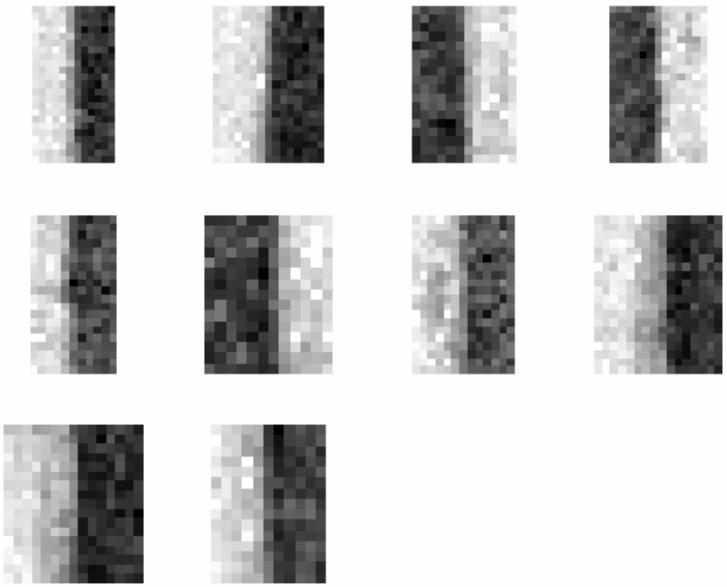
analog

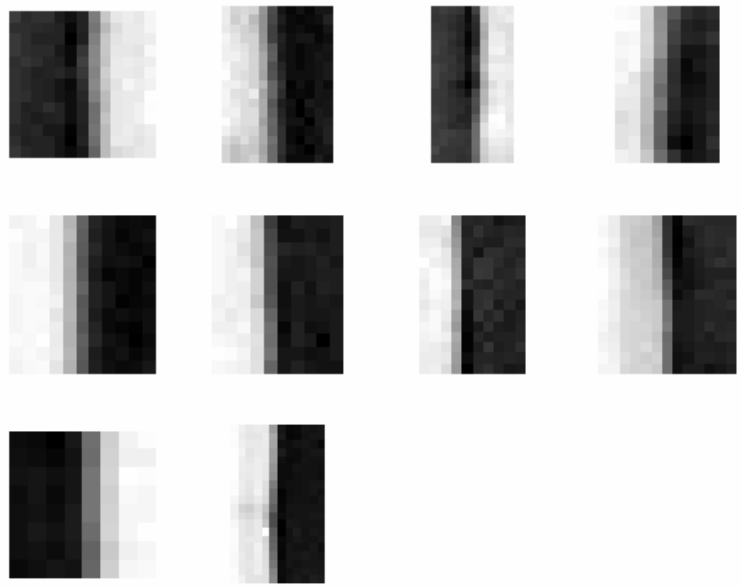
digital

Imagery courtesy of Sanborn Map Company

Edge Profiles (normalized)

- Data set 2: Morrison





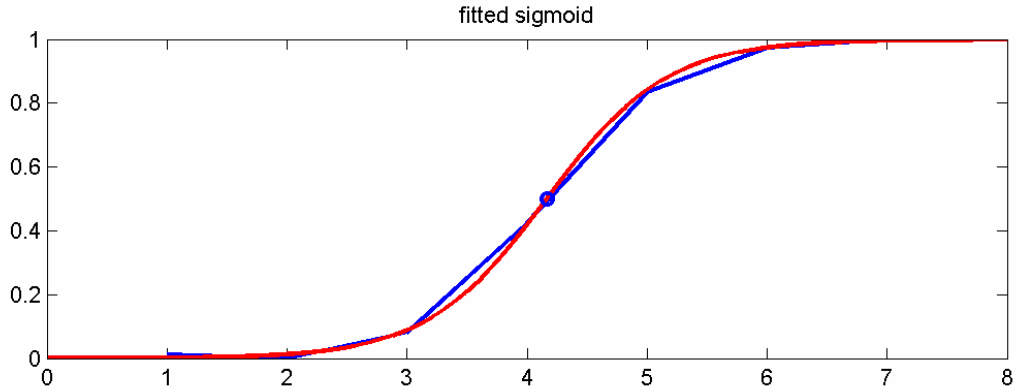
analog

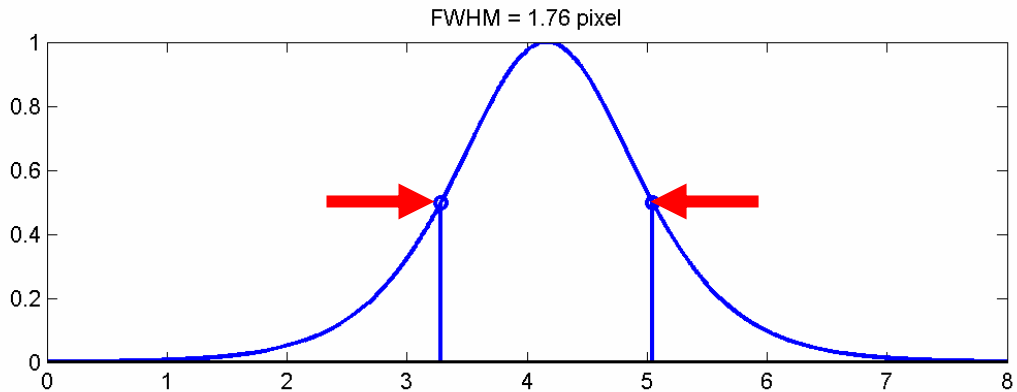
digital

Imagery courtesy of Sanborn Map Company

Edge Response: Test Results

Film:

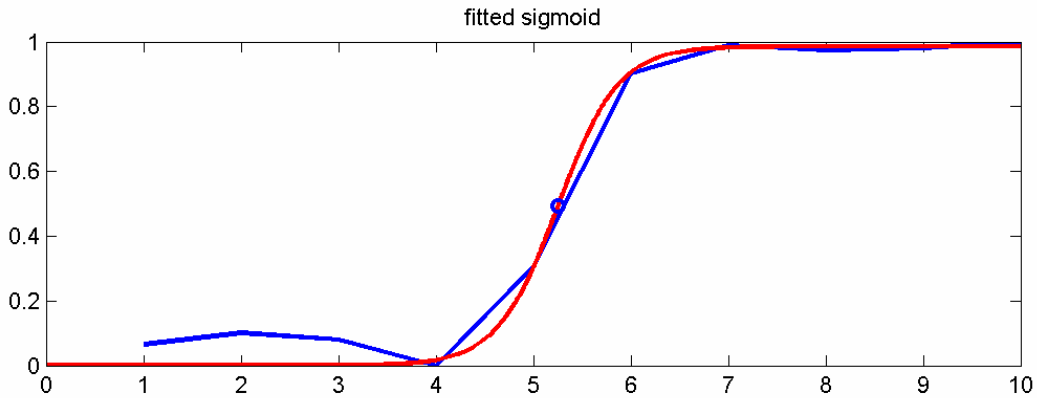


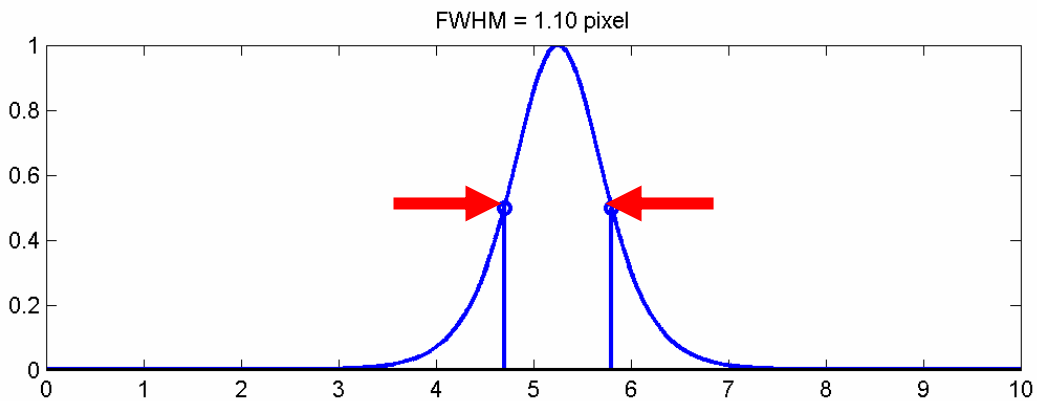


Resolution: 1.8 pixels

Edge Response

Digita





Resolution: 1.1 pixels

Measure of Resolution

- Analog:
  - Resolution: 1.8-2.9 pixels
- Digital:
  - Resolution: 1.1 – 1.9 pixels
- Digital superior by factor of 1.5

- No appreciable difference in resolving power (<0.05 pixels) between
  - digital pan
  - pan-sharpened color band

- Pan-sharpened superior to film in all cases

Digital vs. Film Image Quality

- Visual quality:
  - Better apparent resolution when scanned pixel size (film) is equal to ground pixel size (digital)
  - Clearer detail and texture apparent in smooth (homogeneous) areas
- Information content:
  - More complete matching even in smooth areas
  - More accurate matching
  - Edge detail / measured resolving power is superior

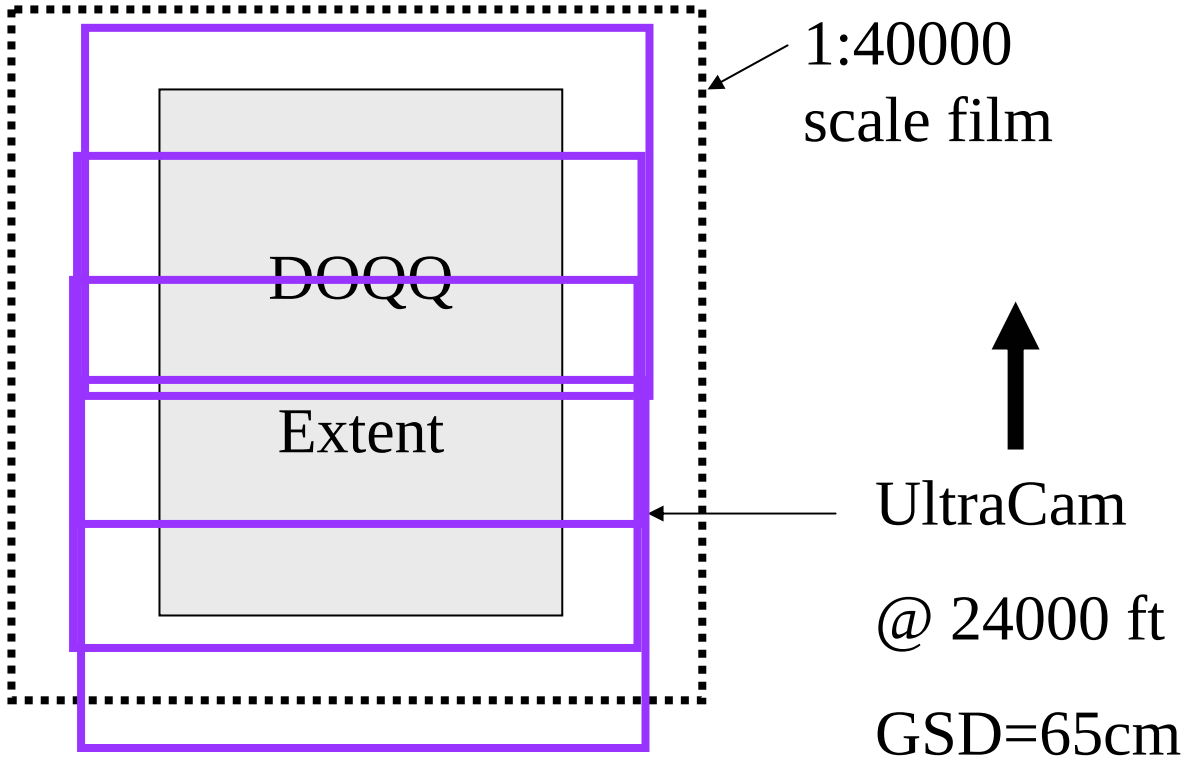
UltraCam-based NAIP Products

Initial Test Results

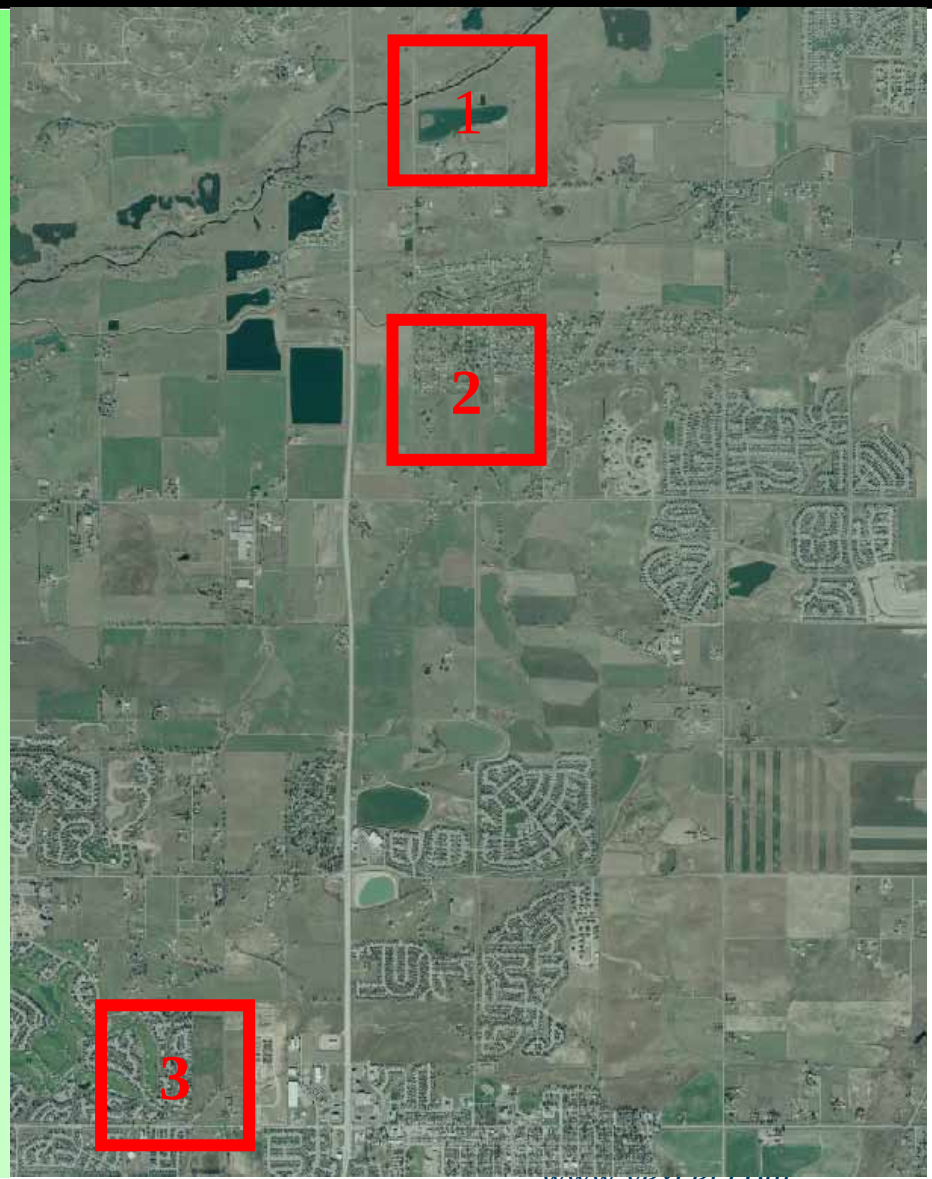
Side-by-side Comparison

- Film:
  - Analog Camera: Leica RC30
  - Flying height: 20,000 feet
  - Scanned using Z/I PhotoScan @21 microns
- Digital:
  - Vexcel UltraCam
  - Flying height: 24,000 feet
- Location:
  - Greeley, Colorado
- Date:
  - November 2004

Collection Geometry

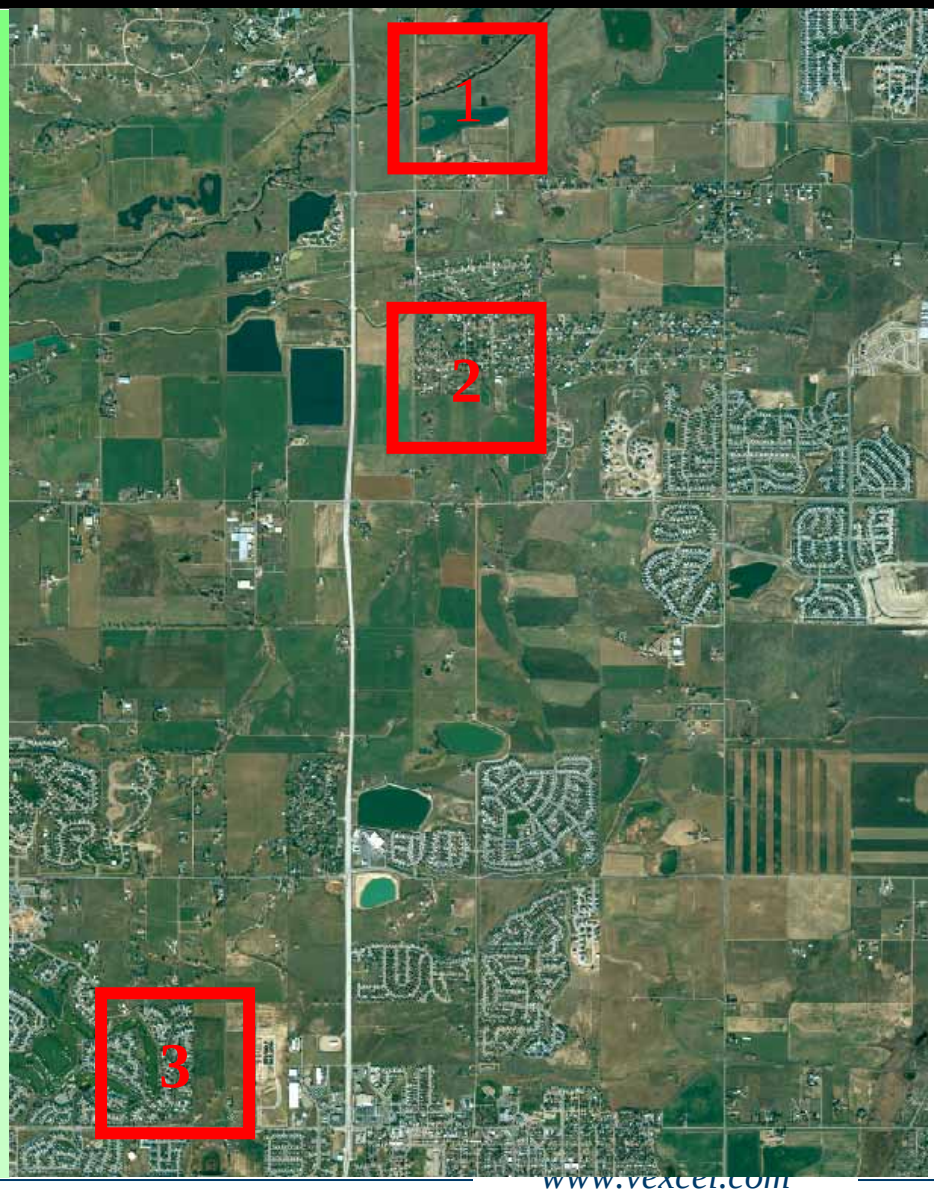


Film-based DOQQ



Imagery courtesy of Sanborn Map Company

UltraCam-based DOQQ



Note:image seams

Side by side comparison - 1

Imagery courtesy of Sanborn Map Company

Side-by-side comparison - 2

Imagery courtesy of Sanborn Map Company

Side by side comparison - 3

Imagery courtesy of Sanborn Map Company

Conclusions

Vexcel UltraCam

- UltraCam designed for maximum geometric and radiometric quality
- The UltraCam produces pan-sharpened products still superior to scanned film based on subjective and quantitative analysis
- Increased information content permits wide range of additional, automated applications and analysis
- Production workflow can be streamlined only with fully-digital workflow

Acknowledgements

- Sanborn Map Company
  - UltraCam flight operations, production and analysis
  - Film imagery
- Roland Perko, Technical University Graz
  - Film / digital / pansharpening imagery analysis

Thank You

Joe Thurgood
Director, Aerial Photogrammetry Products
Vexcel Corporation, Boulder Colorado
Email: joe.thurgood@vexcel.com
Phone: +1.303.583.0250